CAPILLARY HYDRAULIC JUMP IN A PLATEAU BORDER

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Applications to foam drainage

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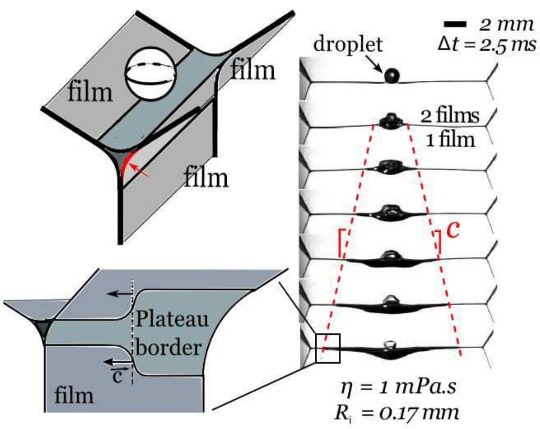
By means of experimental measurements, we study transient flows of liquid along a single Plateau border (PB). In opposition with a common belief, we show that a fast, inertial regime of flow, very little dependent on the fluid viscosity, can be encountered in the high surface mobility limit.

This newly observed regime evolves into the regular viscous regime after a critical distance that can be as large as several centimeters for very dry foams. We show that the liquid redistribution is triggered by an effective negative surface tension [1] that results from the distinctive geometry of the PBs. The dynamics is characterized by the formation of a hydraulic jump, which travels at a constant and substantial velocity (0.1 to 1 m.s^{-1}). The relevant Reynolds number is much larger than one, even for micrometer-thick PBs. Therefore, the now widely acknowledged "drainage equation" [2], which results from effective-medium models of flow through porous media and assumes low Reynolds numbers, fails to describe this capillary-inertial regime, even though it satisfactorily accounts for all previous experiments on foam drainage. However, most of these experiments were performed at the scale of the foam sample, considered steady regimes, and focused on the effects of gravity or of the interfacial rheology; only few experiments investigated the effect of the capillary suction [3, 4].

To account for the observed motion of the hydraulic jump, we propose a theoretical description which accounts for our experimental data. The critical distance over which the inertial regime is observed is correctly predicted.

The impact of the present study on the foam drainage dynamics is also discussed. The inertial regime should be observed in macroscopic experiments as a transient feature of drainage under gravity, or in the local flow occuring along the Plateau borders during topological rearrangements of bubbles [5]. Moreover, this regime should be relevant to describe the exact shape of the imbibition front in forced drainage experiments [6].



Figures: *top left: the experiment consists in dropping a droplet of the same surfactant solution on a single, horizontal PB. Right: The set of snapshots shows the relaxation of the local perturbation after coalescence of the droplet with the PB. Bottom left: outline of the capillary hydraulic jump geometry.*

References

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